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PHOTOELASTIC INVESTIGATION OF THE STATE OF STRESS IN THE CROSS-SECTION OF THE STRAW STALK

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The subject of this paper is the model photoelastic test of the stress distribution in the cross-section of the straw stalk. Approximately we may assume that the straw consists of two materials, having different moduli of elasticity. One of them is sclerenchyma, the other one, parenchyma. The modulus of elasticity of the sclerenchyma is 10—20 times greater than that of the parenchyma. The photo of the cross-section of the straw stalk is shown in Fig. 1.

The models of the cross-section of the straw stalk were made of photoelastic material, the modulus o felasticity of which was $2.5 \cdot 10^9$Pa. Investigations were made on three models. The outside diameter d_z of the first, ring-like shaped model was 170 mm long, while the inside diameter d_w was 110 mm long, which corresponds to dimension proportions in the prototype. In the second model a large number of cell-simulating holes were made in order to preserve the model similarity. The holes were bored in the inner part of the model, which is the counterpart of the layer of parenchyma in the prototype. At the same time, these holes caused a decrease of the modulus of elasticity of this part of the model (taken as a continuum). In the third model a greater number of holes were made than in the second one. The outside dimensions of all the models were the same. The models were under a point-load acting along their diameters. Such a load corresponds to the forces which act upon the stalk while is is being cut or pressed.

Special methods were elaborated to measure the modulus of elasticity of both the solid model and the models with a perforated layers. The modulus of elasticity was evaluated by measuring the shortening of the ring diameter due to compressive force. The shortening was measured in the direction of the applied force.

The relationship between force applied F and a change Δd in a diameter of a ring is known from the theory of elasticity (Fig. 2).

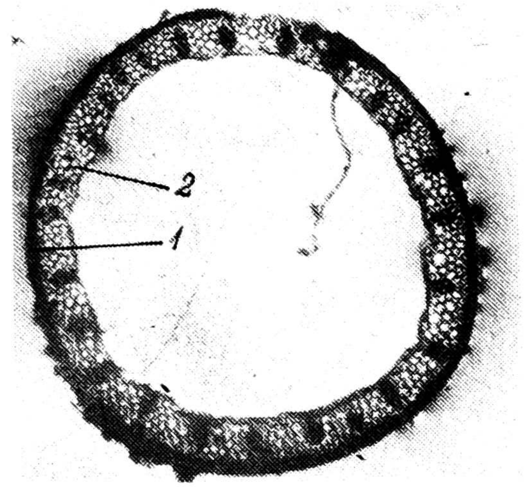

Fig. 1. Cross-section of straw stalk. 1 — sclerenchyma, 2 — parenchyma

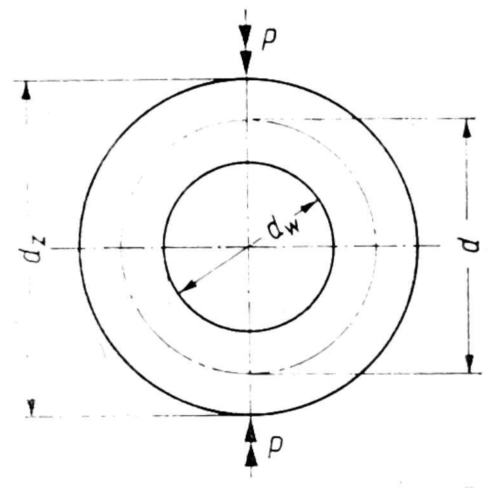

Fig. 2. Moduls of elasticity evaluation method

$$\Delta d=\left(\frac{\pi}{4}-\frac{2}{\pi}\right)\frac{Fd^3}{8EJ}\approx 0{,}00185\frac{Fd^3}{EJ} \tag{1}$$

where:

d — average diameter,

$$d=d_w+\frac{d_z-d_w}{2}=\frac{d_z+d_w}{2},$$

F — compressive force,

E — modulus of elasticity,

J — moment of inertia of the ring cross-section area.

The modulus of elasticity may be found using the equation (1)

$$E=\frac{0.00185Fd^3}{\Delta d\cdot J} \tag{2}$$

If we assume that the cross-section of the ring is not deflected, then $\Delta d = \Delta_z = \Delta d_w$. The change in the inside diameter d_w was measured by means of a rod gauge with a dial indicator. The measuring set for the evaluation of the modulus of elasticity is shown in Fig. 3. The modulus of elasticity values obtained by this method were, respectively, for the first model (solid ring) — $2.47 \cdot 10^9$Pa for the second model — $1.48 \cdot 10^9$Pa and for the third one — $1.25 \cdot 10^5$Pa.

Photoelastic investigations were made by means of polariscope shown in Fig. 4.

The model was placed in the loading system especially adapted for this purpose (see Fig. 4). Measurements were taken by applying two different compressive forces — 186 N and 380 N. The photos of isochromatics in models, taken under 186 N load are shown in Fig. 5.

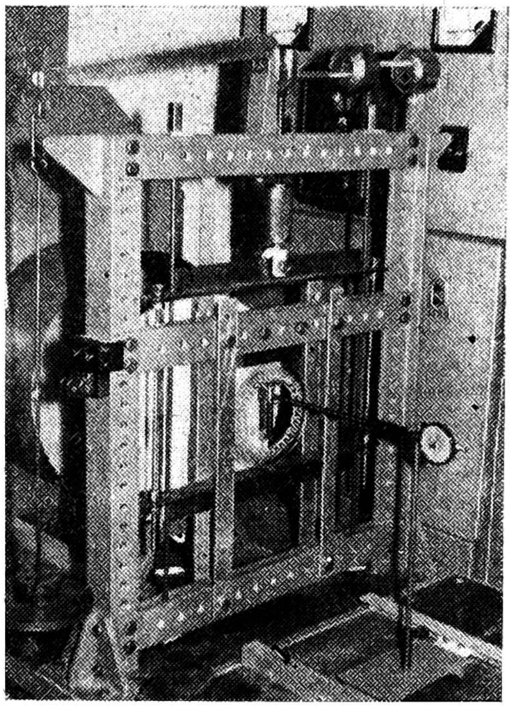

Fig. 3. Measuring set for evaluation of moduls of elasticity

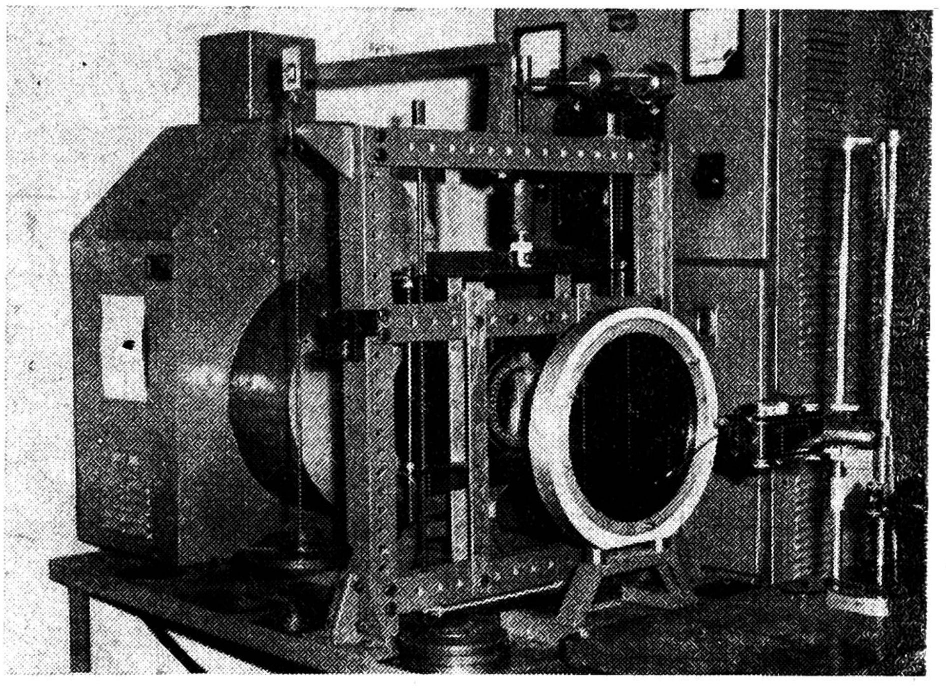

Fig. 4. Polariscope for model tests of straw stalk cross-section

On the basis of photos of isochromatic patterns the boundary stresses distribution was obtained. The isochromatic patterns and the boundary stresses distribution in three models under 380 N load are shown in Fig. 6.

Full measurements of the fringe order were taken by means of the Senarmont compensation method.

From the boundary stresses analysis it appears that stresses distribution is more uniform in the models with the perforated layer than the one in the solid model. Maximum values of boundary stresses in the per-

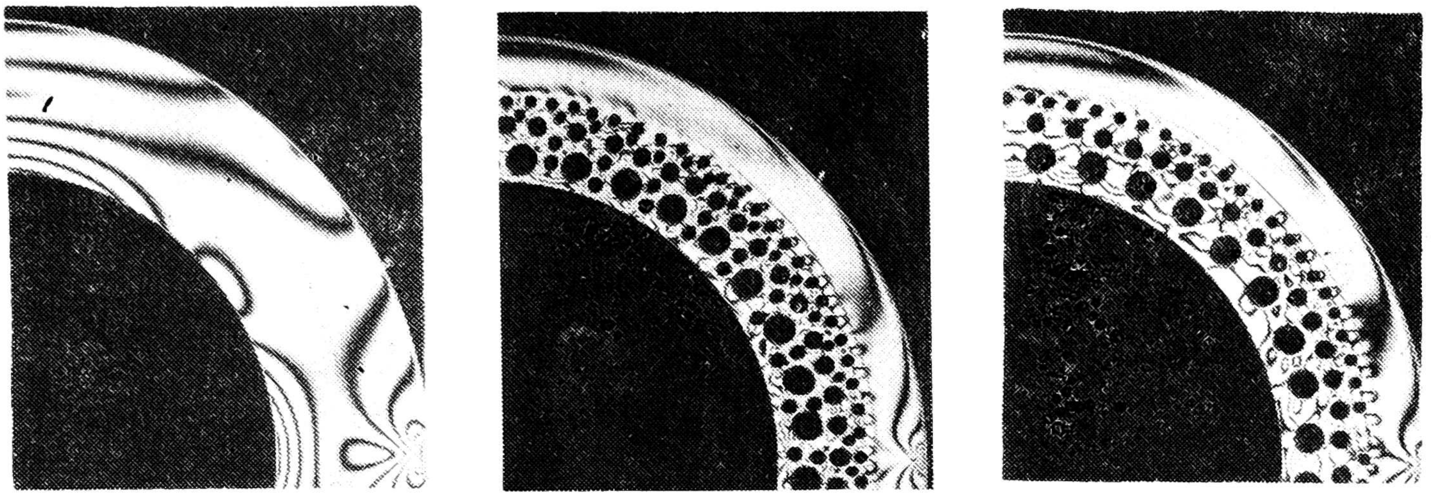

Fig. 5. Isochromatic patterns in models under 186 N kgf load

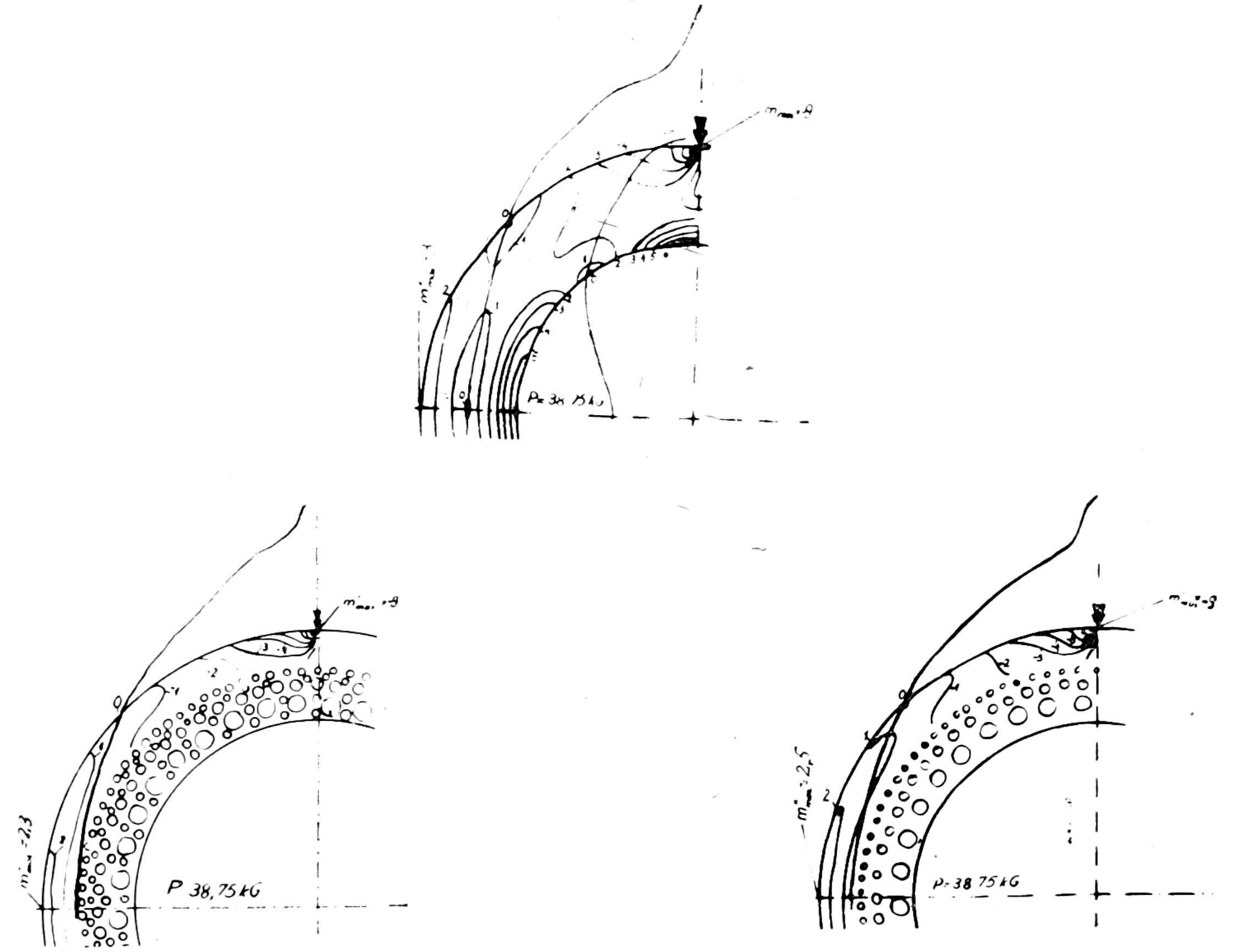

Fig. 6. Isochromatic patterns and boundary stresses distribution in models under 380 N load

forated models are by ca. 20% lower than those in the solid model. It is especially visible in the diametrical cross-section which is perpendicular to the direction of the force. In this cross-section, on the outside edge of the model, the fringe orders were, respectively, in the first model, $m = 3.00$, in the second one, $m = 2.50$ and in the third one, $m = 2.30$.

The inner, perforated part of the third model was cut off to make possible the evaluation of the modulus of elasticity of this part. The measurements were made by the method described above. The average modulus of elasticity of the perforated layer was 1,95 kgf/cm^2. This value is about 13 times lower than that in the solid model. It means that model similarity laws with respect to the moduli of elasticity of model parts and parts of straw were preserved.

The results obtained from the photoelastic tests give information about the state of boundary stresses in the cross-section of straw stalk while it is being compressed. Such load corresponds to the forces which act upon the stalk in the initial phase of mechanical cutting or pressing of the straw.

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ELASTOOPTYCZNE BADANIA STANU NAPRĘŻEŃ W PRZEKROJU POPRZECZNYM ŹDŹBŁA SŁOMY

Streszczenie

W pracy przedstawiono elastooptyczne badania stanu naprężeń w przekroju poprzecznym źdźbła słomy.

Pomiary przeprowadzono na modelach wykonanych z materiału, wykazującego zjawisko optycznej dwójłomności wymuszonej. Przebadano trzy różne modele poprzecznego przekroju źdźbła słomy. Pierwszy model miał kształt pełnego pierścienia, w drugim i trzecim modelu, które miały również kształt pierścieni, wywiercono w ich wewnętrznych częściach liczne otworki, prostopadłe do badanego przekroju. Wskutek tego zmniejszono moduł sprężystości wewnętrznej warstwy przekroju. W ten sposób nadano modelom charakter dwufazowy, odpowiadający w przybliżeniu rzeczywistej budowie źdźbła słomy, zachowując jednocześnie podobieństwo geometryczne.

Podczas badań modele były obciążone siłą skupioną, działającą wzdłuż średnicy przekroju. Takie obciążenie odpowiada siłom działającym na źdźbło w czasie jego ścinania lub prasowania.

Otrzymane z elastooptycznych badań wyniki dostarczają informacji o stanie naprężeń brzegowych poprzecznego przekroju źdźbła słomy.

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ФОТОУПРУГИЕ ИССЛЕДОВАНИЯ СОСТОЯНИЯ НАПРЯЖЕНИЙ В ПОПЕРЕЧНОМ СЕЧЕНИИ СТЕБЛЯ СОЛОМЫ

Резюме

В работе представлены фотоупругие исследования состояния напряжений в поперечном сечении стебля соломы.

Измерения провели на моделях, изготовленных из материалов, обнаруживающих явление временного оптического деупереломления. Испытывали три различные модели поперечного сечения стебля соломы. Первая модель имела форму полного кольца, во второй и третьей, имеющих также форму колец, в их внутренных частях просверлили многочисленные отверстия, перпендикулярные к исследуемому сечению. Вследствие этого уменьшили модуль упругости внутреннего слоя сечения. Таким образом сообщили моделям двухфазный характер, соответствующий в приближении действительному строению стебля соломы, сохраняя одновременного геометрическое сходство.

Во время исследований модели были нагружены накопленной силой, действующей вдоль диаметра сечения. Такая нагрузка соответствует силам, действующим на стебель во время его срезывания или прессования.

Результаты, полученные из фотопругих исследований, дают сведения о состоянии краевых напряжений поперечного сечения стебля соломы.

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